PATENT SPECIFICATION (11) 1 520 490

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(21) Application No. 50176/75 (22) Filed 8 Dec. 1975
(31) Convention Application No. 2 458 862
(32) Filed 12 Dec. 1974 in
(33) Fed. Rep. of Germany (DE)
(44) Complete Specification published 9 Aug. 1978
(51) INT CL² B01F 5/06//B29B 1/06
(52) Index at acceptance B1C 10 14 19G4B 19GU 1 5 X26

(19)

(54) CONTINUOUS MIXING METHOD AND APPARATUS

(71) We, WACKER-CHEMIE G.M.B.H., a body corporate organised according to the laws of the Federal Republic of Germany, of 8 München 22, Prinzregentenstrasse 22, Federal Republic of Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and apparatus suitable for the continuous mixing of solids with solids and/or with flowable compositions and/or with gases.

There are various general desiderata for a mixing method, namely that it should be carried out rapidly, thoroughly, gently, and continuously. In order that mixing is adequately thorough, short mixing times can usually be achieved only by using high operating speeds. With high operating speeds, however, there is greater friction and thus a tendency for milling to occur as well as mixing. In order for mixing to be carried out continuously, the mixer should have a self-cleaning action.

Solids are often mixed in so-called forced mixers, in which the mixing action is the result of purely mechanical forces. These are generally designed for discontinuous operation. Such mixers can be sub-classified into kneading mixers, thrust mixers, throw mixers, and intensive mixers, in increasing order of the intensity of the mixing action.

Kneading mixers are slow-speed forced mixers in which mixing is caused by a circular movement of the particles at varying circumferential speeds dependent on the coefficients of friction between the various materials and the internal surfaces of the mixer. The mechanical stress in such mixers is low and the heat of friction is negligible. These mixers have the disadvantages of requiring long mixing times and of not having a self-cleaning action, making them unsuitable for continuous operation.

Thrust mixers also operate at relatively low speeds. In these mixers, the mixing action is caused by thrust movements along the container wall and in the material to be mixed.

Throw mixers are similar in design to thrust mixers. They can, however, be operated at substantially higher speeds, but this can result in an undesirable increase in the temperature of the material to be mixed. Mixing is caused by throw movements, and therefore the mixing chamber can only be filled to an extent of 60 to 80% of its volume.

One limitation common to kneading mixers, thrust mixers, and throw mixers is that "roller formation" can occur. This is the deposition of the material to be mixed on and between tools with the result that it rotates synchronously with these.

Intensive mixers are rather more closely related to mills and they rely on high impact and impingement effects. In such mixers, little attention can be paid to the protection of the material to be mixed.

A separate class of mixers consists of continuous mixers. These have both a mixing and a conveying action. They generally contain, at any one moment, only a relatively small amount of material, as compared with the amount contained in discontinuous mixers; although large throughputs can be achieved, these can require expensive apparatus features. These mixers are generally operated in the lower to middle speed ranges, but the heat of friction generated in them can be considerable. They can operate in a self-cleaning manner.

British Patent Specification No. 1 159 472 describes and claims a concentric-cylindrical rotary mixing apparatus suitable for the mixing of flowable, preferably highly viscous, compositions, which apparatus comprises a cylindrical rotor having on its curved surface axially, radially or helically arranged studs or studs arranged in any combination of these configurations or axially, radially or helically arranged ribs, or a combination of such ribs and studs and a

coaxial cylindrical stator, having studs or ribs on its inner surface arranged in any of the possible configurations for the studs and ribs on the rotor, there being a gap of annular cross-section between the highest raised surface parts of the rotor and the highest raised internal surface parts of the stator. The apparatus as described in the cited specification is not suitable for the mixing of solids with solids and/or with flowable compositions and/or with gases, since solids would not diffuse in the same way as flowable compositions but would be flung by the rotor into the grooves of the stator. The solids would become jammed in these grooves thus blocking the apparatus and preventing or hindering the introduction of further material. There would also be the danger of the material becoming overheated and even of combustion occurring.

The present invention provides a mixing apparatus having a feed zone and a mixing zone so arranged that solids can be passed into the feed zone and from there into the mixing zone, the apparatus comprising a stator with a rotor coaxially situated therein and rotatable about its longitudinal axis, and with an annular gap between the outer surface of the rotor and the inner surface of the stator, a first part of the annular gap towards one end of the rotor constituting the feed zone and a second part of the annular gap towards the other end of the rotor constituting the mixing zone, the part of the rotor within the feed zone and the part of the rotor within the mixing zone each being of cylindrical or conical or frustoconical shape with, in the case of a conical or frustoconical shape, an apex angle of not more than 30° and the corresponding parts of the stator being of similar shape, the part of the rotor within the feed zone having on its surface a feed screw, and the part of the rotor within the mixing zone and the part of the stator within the mixing zone having on their respective surfaces studs, ribs or like projections, and the longitudinal axial length of the part of the rotor within the feed zone constituting from 5 to 40% of the total longitudinal axial length of the rotor within the two zones.

This apparatus is suitable for the mixing of solids with solids and/or with flowable compositions and/or with gases. It has a self-cleaning action and is therefore suitable for continuous operation. It can give a rapid mixing operation, that is a short residence time of the material in the mixer and thus a large throughput, combined with an adequate protection of the material.

The parts of the rotor and stator within the mixing zone of the present apparatus, in so far as such parts may be cylindrical, may correspond to the previously mentioned apparatus according to British Patent Specification No. 1 159 472. The present apparatus differs from the said previous apparatus, however, at least in that it includes a feed zone, which makes it suitable for use with solids as well as flowable compositions.

Each part of the rotor in the present apparatus, that is the part within the feed zone and the part within the mixing zone, may be of cylindrical or conical or frustoconical shape, but the two parts need not be of the same shape as one another. Advantageously, however, the two parts are of the same shape as one another; this makes for ease of manufacture and assembly of the apparatus. The two parts of the stator should be of similar shape to the respective parts of the rotor.

In the case of rotors that are conical or frustoconical in at least one of the two zones, the apex should be not more than 30°. With rotors of this shape, the material passing through the apparatus travels at a continuously increasing or decreasing circumferential speed (according to whether it is passing away from or towards the apex of the cone, respectively). The greater the apex angle the greater is the acceleration or deceleration of the material, and the less uniform is the mixing operation. Thus, it has been found that the apex angle should not exceed 30°, and advantageously should not exceed 10°. Preferably, the entire rotor is cylindrical in shape (that is with an apex angle of 0°).

The design of the feed zone for a particular mixing apparatus depends not only on the intended mixing speed and throughput of the apparatus, but also on the particular material or materials in conjunction with which it is intended to use the mixer. For example, the particle size of the material, the changes which the material may suffer during mixing, such as caking or cavitation, and the stress to which the material may be subjected, such as slip-back or through-slip, have to be borne in mind. On the other hand, the mixing intensity and throughput in the mixing zone depend primarily on the circumferential speed of the rotor.

It can be seen that the design of the feed zone and that of the mixing zone are closely interrelated. For example, if the feed zone is too large in relation to the throughput of the mixer zone, there is a danger of slip occurring in the feed zone. This can result in a non-uniform supply to the mixing zone and in a blockage with a consequent release of pressure in the mixing zone. This, in turn, can result in poor mixing, overheating, degassing, or changes in the structure of the material. The conveying capacity of the feed zone thus depends on the capacity of the mixing zone. It is determined by

amongst other things, the profile and pitch of the feed screw.

It is generally advantageous for the surface of the part of the rotor within the feed zone to be polished, and for the surface of the part of the stator within the feed zone to be roughened or provided with studs, ribs or like projections. The polish of the screw on the rotor ensures solely a pressing action, whereas the roughened, studded or ribbed surface of the stator prevents a mere rotation of the material.

It is also generally advantageous for the two parts of the rotor to be so mounted on a single drive shaft that they can be rotated at the same rotational speed. In certain cases, however, it can be preferable for the two parts of the rotor to be driven independently of one another. This can be useful if the apparatus is intended for use in several different mixing operations. It can also be advantageous if particularly high circumferential speeds are to be used in the mixing zone, since roller formation could occur if such speeds were used in the feed zone.

The longitudinal axial length of the part of the rotor within the feed zone should be from 5 to 40% of the total longitudinal axial length of the rotor within the two zones. Advantageously, however, it is not more than 20% of the said total length. The length:diameter ratio of the rotor is chosen according to the desired residence time and throughput of the mixing apparatus. In any given mixing apparatus, it is possible to vary the throughput to some extent by varying the speed of the rotor.

The parts of the rotor and stator within the mixing zone are provided on their respective surfaces with studs, ribs or like projections. These may be arranged in any suitable configuration, for example, axially, radially or helically. Advantageously, the arrangement of the studs, ribs or like projections on the rotor is helical, as this assists in conveying the material through the apparatus.

A particularly preferred arrangement is for the part of the rotor within the mixing zone to be provided with lozenge-shaped studs so arranged that the sides of the studs define two helices of different pitch, the pitch angle of one helix preferably being within the range of from 15° to 30° and that of the other helix preferably being within the range of from 45° to 60°. The two helices may run in the same or contrary senses, but it is preferred that they run in the same sense as this gives an apparatus of larger capacity.

Advantageously, the width of the annular gap is measured between the highest raised surfaces on the rotor and the highest raised surfaces on the stator does not exceed the height of the studs, ribs or like projections. The width is chosen according to the consistency and miscibility of the material intended to be used in the apparatus. If the particle size of the solids material is greater than the width of the annular gap, then the material is partially milled while passing through the mixing apparatus and this can be advantageous.

If the apparatus is to be used for the mixing of particularly sensitive materials, undesired shearing forces can be eliminated by rounding off the studs, ribs or like projections.

Further details of the studs, ribs or like projections and of other features of the mixing zone will be apparent from British Patent Specification No. 1 159 472.

When the apparatus is to be used for the mixing of solids with flowable compositions and/or with gases, it can be advantageous to provide inlets, for example ring nozzles, through which the flowable compositions and/or gases can be introduced directly into the mixing zone while the solids are introduced *via* the feed zone. If desired, the flowable compositions and/or gases can, however, also be introduced *via* the feed zone.

The apparatus may comprise heating means and/or cooling means. These may, for example, be provided within the rotor or within the stator.

The mixing apparatus according to the invention, and especially the preferred form thereof, has the advantages of thrust and throw mixers in that it treats the material gently and also the advantages of intensive mixers in that short mixing times can be achieved. High impact and impingement effects are avoided, particularly in apparatus with helically arranged studs, ribs or like projections, since the product slides over a sloping plane corresponding to the pitch angle. During this movement, the particle acceleration is primarily tangential, with the particle in the surface of the material flowing at an acute angle. Thus, penetration of the product is avoided and the diffusion of particles from the rotor to the stator and *vice versa* is achieved.

In chemical reactions, it is frequently desired to mix solids with solids and/or with flowable compositions and/or with gases, and the present aparatus can be used for the carrying out of chemical reactions. In this way it is possible to achieve a rapid contact of the reactants with one another, or a rapid removal of, for example, water from the solids surface by mixing the solids material with a gas. By the use of appropriate heating or cooling means, it is possible to achieve a rapid supply or removal of heat. If the reaction is a slow one, the short residence time in the mixer may be

insufficient. In this case, the reaction may be completed, for example, in a residence container into which the material subsequently passes or by the return of part of the material to the apparatus, optionally *via* a heat exchanger.

The apparatus of the invention is particularly suitable for the carrying out of reactions in which the reaction speed is affected by the intensity of mixing of the reactants. Such reactions are, for example, those involving solid catalysts, *e.g.* polymerisation reactions, and reactions of polymers with monomers or with other polymers; hydrolysis reactions, *e.g.* the manufacture of vinyl alcohol homopolymers and copolymers from vinyl acetate homopolymers and copolymers; and acylation, amidation and cyclisations reactions of difficulty soluble compounds, *e.g.* ureas.

One form of apparatus according to the invention and a method of using it will now be described, by way of example only, with reference to the accompanying drawings, in which

Fig. 1 is a diagrammatic representation of a plant including one form of apparatus according to the invention,

Fig. 2 is a semi-diagrammatic view partly in longitudinal cross-section, of one form of apparatus according to the invention, and

Fig. 3 is a semi-diagrammatic view, partly in longitudinal cross-section, of part of one form of apparatus according to the invention, showing in particular the rotor and the stator.

The mixing apparatus comprises a cylindrical stator 27 with a cylindrical rotor 30 coaxially situated therein and rotatable about its longitudinal axis by means of a drive shaft 24 contained within a housing 23 and driven, optionally *via* gears, by means of an electric motor (not shown). There is an annular gap 31 between the outer surface of the rotor 30 and the inner surface of the stator 27. One part of the rotor 30 is provided on its surface with a feed screw 25 and the annular gap 31 in this region constitutes a feed zone 32. The part 26 of the rotor 30 immediately below the feed zone 32 is provided on its surface with lozenge-shaped studs so arranged that their sides define two helices of different pitch, as can clearly be seen in Fig. 3. The annular gap 31 in this region constitutes a mixing zone 33. The axial length of the part of the rotor 30 within the feed zone 32 constitutes 23.5% of the axial length of the rotor 30 within the feed zone 32 and the mixing zone 33. The inner surface of the stator 27 is provided with studs within both the mixing zone 33 and the feed zone 32. Immediately above the feed zone 32, the drive shaft 24 passes through a funnel-shaped section of housing, in which it is provided with a feed screw 34 of greater pitch than the feed screw 25. This constitutes a delivery zone 28.

Solids materials can be passed from a hopper 1 by means of a screw conveyor 2 driven by a motor 3 through an inlet 4 into the delivery zone 28. Likewise, solids material can be passed from a hopper 5 by means of a screw conveyor 6 driven by a motor 7 through an inlet 8 into the delivery zone 28. From the delivery zone 28, the solids materials entering through inlets 4 and 8 are passed by the rotation of the drive shaft 24 into the feed zone 32 and then into the mixing zone 33. Flowable compositions and/or gases can be introduced directly into the mixing zone 33 from tanks 9*a*, 9*b*, *via* piston pump 10 and geared pump 11 respectively, pulsation dampers 12*a*, 12*b* respectively, flow meters, 13*a*, 13*b* respectively, and inlets 14*a*, 14*b* respectively. The solids materials and flowable compositions and/or gases are mixed in the mixing zone 28 by the action of the rotation of the rotor 30, and the resulting mixture subsequently leaves the apparatus through an outlet (not shown) below the mixing zone 33.

The part of the stator 27 within the region of the mixing zone 33 is surrounded by a jacket 35 for a heating fluid or cooling fluid, which can proceed from a heater or cooler 15 *via* an inlet 16 to the jacekt 35 and then be returned *via* an outlet 17 to the heater or cooler 15.

Above the delivery zone 28, the drive shaft 24 is provided with a shaft seal 20 into which a sealing liquid can be pumped through an inlet 19 by means of centrifugal pump 18. The sealing liquid can subsequently leave the shaft seal 20 through an outlet 21 and its pressure can be read by a manometer 22.

The following example illustrate the use of the apparatus according to the invention. The apparatus used was in each case similar to that shown in the drawings. The sealing liquid used in the shaft seal 20 was water in each case, except for Examples 5 and 6 where it was edible oil (livio).

Example 1.
Preparation of dry blends.

100 parts of emulsion polyvinyl chloride (PVC) (K-value 70), 25 parts of benzylbutylphthalate (BBP), and a mixture of 2 parts of azodicarbonamide 2 parts of a barium zinc accelerator (type 228), 2 parts of dibutyl tin mercaptide (Irgastab 17 M; Trade Mark), 3 parts of a epoxidised soya bean oil (Reoplast 39; Trade Mark), 45 parts of titanium dioxide (Kronus RN 56; Trade Mark), 0.5 parts of a paraffin oil (Irgawax 360; Trade Mark) and 35 parts of dioctylphthalate (DOP), were metered into the mixing apparatus. The PVC was

metered in through the inlet 4, and the other two components were metered in through the inlets 14*a* and 14*b*. The temperature of the mixing zone was maintained at 112°C. The PVC-throughput was 30 kg/h, the speed of the rotor was 1700 rev/min.

The product emerged from the mixing zone uniformly mixed, in the form of a readily flowable, very loose, dry powder, yellow in colour on account of the content of azodicarbonamide.

Example 2.

Preparation of dry blends.

The procedure of Example 1 was carried out except that the azodicarbonamide was omitted. The powder mixture obtained was pure white, and could be used to produce flawless films on a calender.

Example 3.

Preparation of white bread dough.

100 parts of wheat flour, 1 part of miliose, and 55.5 parts of a mixture of 50 parts of water. 1.5 parts of salt, 2 parts of yeast and 2 parts of fat (voltem) were introduced into the mixing apparatus through the inlets 4, 8 and 14*a* respectively. The jacket of the mixer was cooled with water. The speed of the rotor was 1700 rev/min, and the throughput of flour was 48 kg/h. The temperature of the dough obtained was just 40°C. The dough rose satisfactorily and could be used for producing white bread or rolls, which were light and showed a uniform pore structure.

Example 4.

Preparation of a wholemeal bread.

The procedure of Example 3 was repeated except that, instead of the 100 parts of wheat flour, the same quantity of wheat grains was used. Mixing and crushing could thus be carried out in one working step. Wholemeal bread produced from the dough obtained was satisfactory as regards taste and structure.

Example 5.

Preparation of block chocolate.

Approximately 40 kg of cocoa paste were dehydrated for 24 hours (residual water *ca.* 0.25 %) at 80°C *in vacuo* (approximately 1 mm Hg) and subsequently mixed with 5 kg of cocoa butter and 0.5 kg of lecithin. This mixture, preheated to 80°C, was metered into the mixing apparatus through the inlet 14*b*, at a rate of 30 kg/h. 35 kg/h of sugar was introduced through the inlet 4. The speed of the rotor was 2500 rev/min, and the mixing temperature was 62—63°C. The mixing was good and the product was satisfactory with respect to taste.

Example 6.

Dehydrating cocoa paste.

30 kg/h of cocoa paste that had not been dehydrated was granulated and introduced into the mixing apparatus, heated to 175°C, through the inlet 4. Simultaneously, 34 m^3/h of nitrogen were introduced through the inlet 14*a*. The speed of the rotor was 2500 rev/min. The water content of the cocoa paste heated to 115°C decreased from 1.49 % to 0.87 %.

Example 7.

Mixing polyvinyl alcohol with water.

Polyvinyl alcohol (Polyviol W 25/140; Trade Mark) was introduced into the mixing apparatus through the inlet 4 and water was introduced through the inlet 14*a* in the amounts shown in the table below. The rotor was operated at 2500 rev/min. The mixture emerging from the water-cooled apparatus still contained small lumps, but the following table shows the reduction of the dissolving times. In a comparative test V, the powder was dissolved at room temperature and at 80°C with the addition of water in the same stirring vessel with a stirring device customary in laboratories (magnetic stirrer).

Sample	kg introduced per hr.		Solids content %		Dissolving times (min)	
	water	PVA	theory	found	room temp	80°C
I	48	31	39.2	29.4	35	9
II	62	21.1	25.3	24.2	25	6
III	82	21.1	20.5	19.3	12	3.5
IV	120	19.1	13.7	12.4	3	3
V	0.09	0.01		10.0	120	113

Example 8.

The procedure of Example 7 was repeated at a higher speed (4400 rev/min). Dissolving times were not measured, since the product solidifed to form a uniform viscous mass without any further processing. The throughputs (kg/h) used were substantially higher than in Example 7, but do not represent the limit of the capacity of the mixing plant.

Sample	kg introduced per hour	
	water	PVA
VI	390	94
VII	390	100
VIII	390	111
IX	390	142

Example 9.

Dyeing polyethylene.

211 kg/h of low-pressure polyethylene (KM 6011 P) were introduced into the mixing apparatus through the inlet 4. Simultaneously, 0.207 kg/h of a green dyestuff paste (Rakusol RU 611—PL 3071; Trade Mark), were metered-in through the inlet 8. A rotor speed of 4400 rev/min was used. The powder emerging from the water-cooled mixer consisted of a statistical mixture of weakly dyed and strongly dyed particles. Part of the product was processed to form films, and part was hand pressed through a small extruder to form bars. The films and the bars had a uniform green colouring.

Example 10.

Mixing polyethylene with a cross-linking agent.

211 kg/h of low-pressure polyethylene (KM 6011 P) were introduced into the water-cooled apparatus through the inlet 4 and 1.6 litres of triethoxyvinylsilane were metered-in through the inlet 8 by means of a Lewa (Trade Mark) dosing pump. The rotor was operated at 4400 rev/min. The powder emerging from the mixing unit proved to be a satisfactory homogeneous mixture.

Example 11.

94.7 kg/h of an emulsion PVC which could be made into a paste and had a K value of 70 (E 70 CQ) were introduced into the apparatus through the inlet 4. Simultaneously, 54 kg/h of dioctylphthalate and 65.9 kg/h of a mixture of 50 parts by weight of benzylbutylphthalate, 5 parts by weight of azodicarbonamide, 5 parts by weight of dibasic lead phthalate (Naftovin T 80; Trade Mark), 5 parts by weight of titanium dioxide (Kronos RN 56; Trade Mark), 2 parts by weight of a methacrylic acid ester-butadiene-styrene copolymer (Pavaloid K 120 N; Trade Mark), and 0.5 parts by weight of a paraffin oil as external lubricant (Irgawax 360) were introduced through the inlets 14*a*, 14*b* respectively. The outer jacket of the apparatus was cooled with water. The rotor was operated at 4400 rev/min. The temperature of the paste emerging from the apparatus was approximately 35°C. The paste was excellently homogeneous and had good flow properties.

Example 12.

Dissolving a copolymer of vinyl chloride and vinyl acetate (Vinnol H 15/50; Trade Mark) in dioctylphthalate.

39.8 kg/h of the copolymer were introduced into the mixing apparatus through the inlet 4. Simultaneously, approximately 80 kg/h of dioctylphthalate were metered-in through the inlet 14*a*. The rotor was operated at 2500 rev/min. The two components were mixed satisfactorily and homogeneously. The temperature of the mixture was approximately 60°C.

WHAT WE CLAIM IS:—

1. A mixing apparatus having a feed zone and a mixing zone so arranged that solids can be passed into the feed zone and from there into the mixing zone, the apparatus comprising a stator with a rotor coaxially situated therein and rotatable about its longitudinal axis, and with an annular gap between the outer surface of the rotor and the inner surface of the stator, a first part of the annular gap towards one end of the rotor constituting the feed zone and a second part of the annular gap towards the other end of the rotor constituting the mixing zone, the part of the rotor within the feed zone and the part of the rotor within the mixing zone each being of cylindrical or conical or frustoconical shape with, in the case of a conical or frustoconical shape, an apex angle of not more than 30° and the corresponding parts of the stator being of similar shape, the part of the rotor within the feed zone having on its surface a feed screw, and the part of the rotor within the mixing zone and the part of the stator within the mixing zone having on their respective surfaces studs, ribs or like projections, and the longitudinal axial length of the part of the rotor within the feed zone constituting from 5 to 40 % of the total longitudinal axial length of the rotor within the two zones.

2. An apparatus as claimed in claim 1, wherein the two parts of the rotor are the same shape as one another.

3. An apparatus as claimed in claim 1 or claim 2, wherein each or either part of the rotor is conical or frustoconical in shape with an apex angle of not more than 10°.

4. An apparatus as claimed in claim 1, wherein the entire rotor is cylindrical.

5. An apparatus as claimed in any one of claims 1 to 4, wherein the two parts of the rotor are so mounted on a single drive shaft that they can be rotated at the same rotational speed.

6. An apparatus as claimed in any one of claims 1 to 5, wherein the longitudinal axial length of the part of the rotor within the feed zone is from 5 to 20 % of the total longitudinal axial length of the rotor within the two zones.

7. An apparatus as claimed in any one of claims 1 to 6, wherein the surface of the part of the rotor within the feed zone is polished.

8. An apparatus as claimed in any one of claims 1 to 7, wherein the surface of the part of the stator within the feed zone is roughened or provided with studs, ribs or like projections.

9. An apparatus as claimed in any one of claims 1 to 8, wherein the studs, ribs or like projections on the part of the rotor within the mixing zone are arranged helically.

10. An apparatus as claimed in any one of claims 1 to 8, wherein the part of the rotor within the mixing zone is provided with lozenge-shaped studs so arrange that their sides define two helices of different pitch.

11. An apparatus as claimed in claim 10, wherein the pitch angle of one of the said two helices is within the range of from 15° to 30° and that of the other helix is from 45° to 60°.

12. An apparatus as claimed in claim 10 or claim 11, wherein the said two helices run in the same sense.

13. An apparatus as claimed in any one of claims 1 to 12, wherein the width of the anular gap as measured between the highest raised surfaces on the rotor and the highest raised surfaces on the stator does not exceed the height of the studs, ribs or like projections.

14. An apparatus as claimed in any one of claims 1 to 13, wherein the studs, ribs or like projections have been rounded off.

15. An apparatus as claimed in any one of claims 1 to 14, containing inlets through which flowable compositions and/or gases can be introduced directly into the mixing zone.

16. An apparatus as claimed in claim 1, substantially as described herein with reference to and as shown in the accompanying drawings.

17. A method of mixing a solids material with a solids material and/or with a flowable composition and/or with a gas, wherein mixing is carried out in an apparatus as claimed in any one of claims 1 to 16, with the solids material or materials being introduced into the mixing zone *via* the feed zone and the flowable composition and/or gas, if any, being introduced into the mixing zone either directly or *via* the feed zone.

18. A method as claimed in claim 17, carried out substantially as described in any one of Examples 1 to 12 herein.

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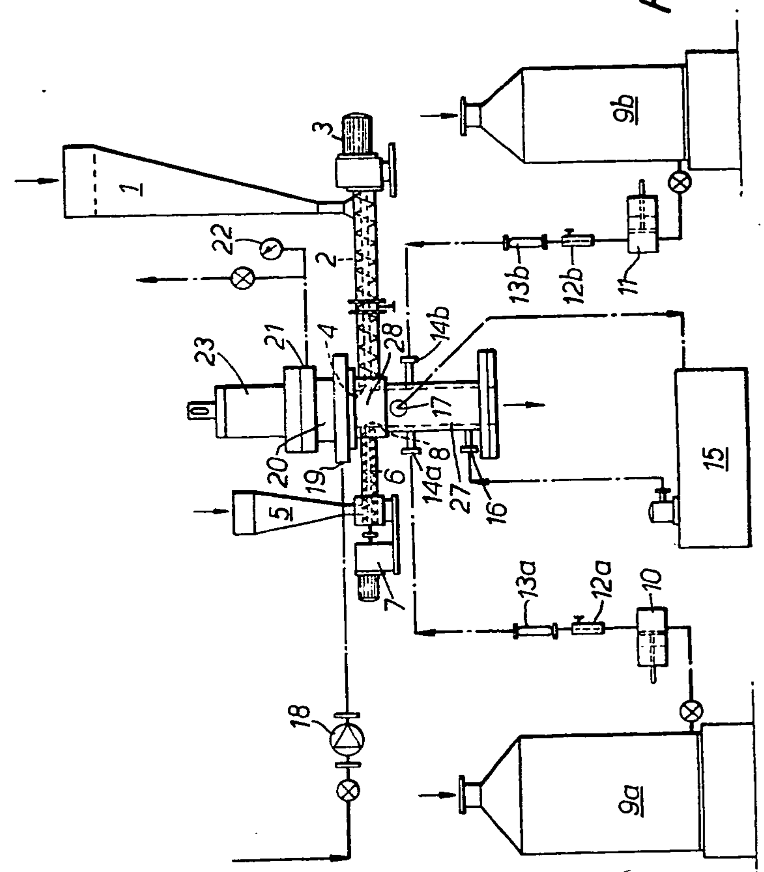
Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1978.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1520490 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.



1520490 COMPLETE SPECIFICATION

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Sheet 2

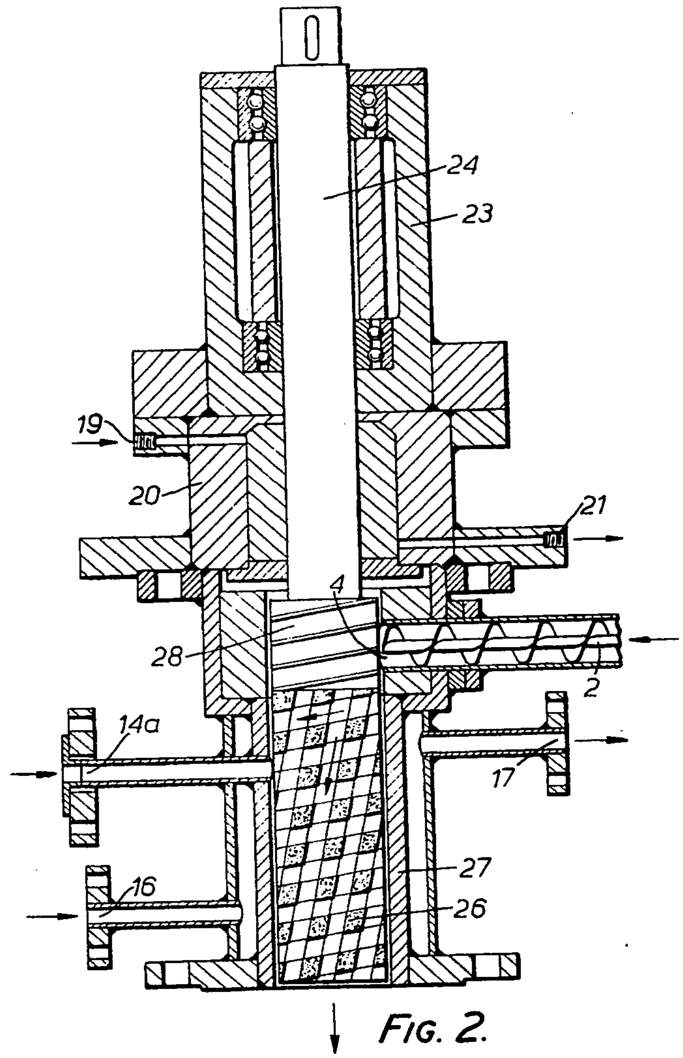

FIG. 2.

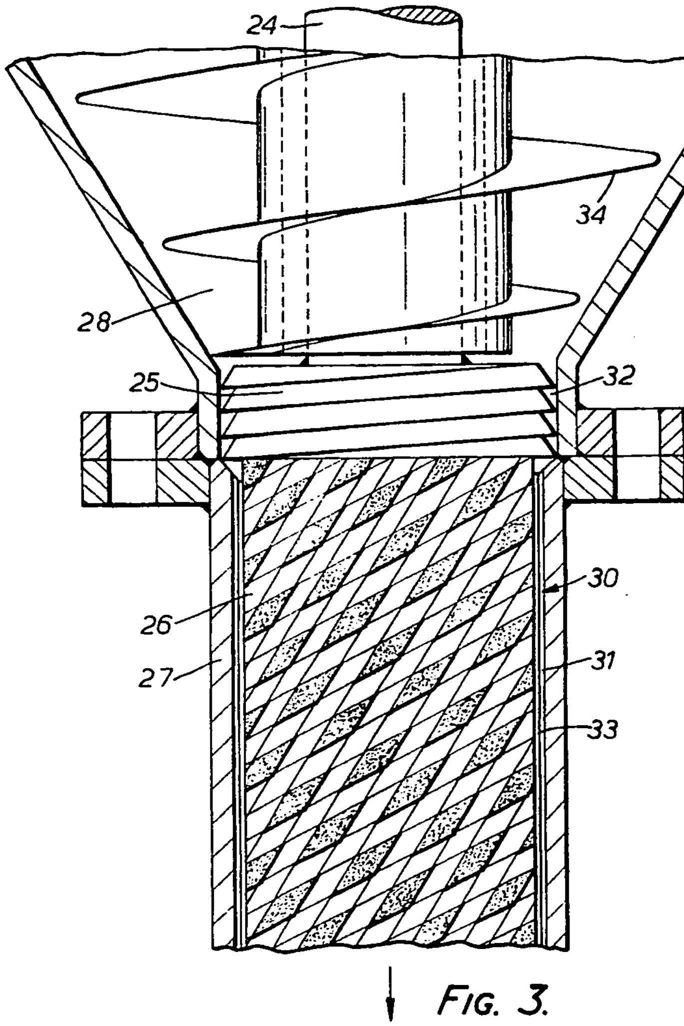

FIG. 3.